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Sustainability Engineering & Maintenance **Plan, Design, and Construct for Maintainability:** **SUSTAINABLE LIGHTING SYSTEMS**



Advances in lighting technologies, innovative daylighting designs, and direct digital control (DDC) systems have enabled more efficient electrical lighting usage. Consideration of long-term operations and maintenance (O&M) requirements with proper planning, design, and installation of lighting systems will maximize return on investment (ROI). These give the Navy the best opportunity to avoid unnecessary rework and repair, and to make cost effective and energy saving decisions. It is important to recognize that a truly sustainable lighting implementation with a satisfactory ROI requires integrated planning and design with other design disciplines such as architectural, building systems such as HVAC and other electrical, the intended usage, geographic, and climate conditions of the facility. This TechData Sheet provides general sustainable strategies on the use of lighting technologies to achieve an effective ROI. Details can be found in UFC 3-530-01, Design: Interior and Exterior Lighting and Controls and in the other published studies from the reference list at the end of this document. Per MIL-STD-3007, Unified Facility Criteria apply to all construction, repair, and maintenance projects and are the DoD criteria for lighting. Information from this TechData Sheet can be used as a guide to “red flag” any

shortsighted design issues during the planning/design phases. NAVFAC Quality Assurance personnel must be familiar with the design intent, performance criteria, and product specifications to field verify that the proper products and systems are installed, tested, and calibrated as specified to ensure proper operation of new systems and integration with other systems. Monitoring, adjustments and fine tuning to actual conditions after installation are needed to ensure optimum performance. Lastly, a well strategized O&M plan will keep on-going cost low and conserve energy as intended by the sustainable design.

SUSTAINABLE ELECTRICAL LIGHTING offers:

- Lower energy usage
- Comparable lighting performance
- Less waste heat
- Longer life
- Higher lumen maintenance

Designing with adequate lighting requirements for each specified use area should reduce over lighting, therefore reducing lamp count. Longer

lamp life and a reduced lamp count will therefore require less replacement material and labor cost.

Electric Lighting Requirements must be designed with the following in mind:

- Consider usage first, not energy, then choose best available technology for energy conservation and reliable O&M.
- Greater amount of lighting downward is an outdated practice and is not good lighting design.
- Surrounding paint and reflective surfaces will affect the lighting design and glare reduction.

Fluorescent lamps are the most widely used lamps in interior environment and currently have the best ROI. They require low maintenance, are energy efficient compared to incandescent, and have lower first cost than HID and LEDs.

Ballasts are required for using gas discharged lamps, which include fluorescent and HID type lamps. Ballast should be selected to match the performance requirements of the lighting design.

- **T8** lamps are the most widely used fluorescent lamps in the building environment. A retrofit from T12 to T8 with high efficiency electronic ballast can save up to 50 percent energy.
- **T5** allow for smaller luminaires (lighting units) in applications such as surface mounted, cove lighting, and cabinetry applications. It is good for high bay ceilings (outdoor or warehouses). When retrofitting with T5 over T8 or T12, the ballasts and the fixtures need to be replaced as well. Therefore, it is mainly applied in new construction. The T5 enables more accurate control of beam direction by means of optics (reflectors and lenses in the luminaires').
- **T5HO** (high output) is rated at 5,000 lumens and performs at elevated temperature. It can provide 60 percent energy savings over metal halide and has 75 percent longer life. T5HO should be considered for warehouse application over HID lamps.

Induction lamps are usually used in elevated outdoor application and warehouse environments, and they are preferable in higher temperature environment over LEDs. They have an extended

rated life at 100,000 hours. Induction lamps also use a lower wattage compared to metal halide, high-pressure sodium or mercury vapor lamps.

Comparing the lamp life of induction lamps to several other lamp types, four to five re-lamping rounds would be needed. The cost of the reduced re-lamping rounds when using induction lamps can have significant ROI by reducing maintenance cost by 400 to 600 percent (Conley).

Light Emitting Diodes (LED) provides uniform lighting and are suitable for outdoor and niche indoor applications, such as walk-in freezers, refrigerated display cases, task lights. When considering Total Ownership Cost (TOC), the current initial high cost of LEDs limits its ROI in certain applications. They are slowly being evaluated in various environments such as outdoor applications to replace the less efficient HID lamps. The cost efficiency of LED will continue to change as prices come down.

High Intensity Discharge lamps (HID) (metal halide & high pressure sodium (HPS)) are usually used in outdoor / indoor high ceilings where a high output is required with a limited space footprint. HPS lights, with poor light quality and high maintenance cost, are being phased out.

Outdoor / Exterior Lighting have high maintenance cost, therefore lighting maintenance savings can far exceed energy savings. Extended life and reliability are critical components in controlling maintenance cost and achieving an adequate ROI.

- The majority of exterior lighting on DoD installations is high pressure sodium HPS, but they are gradually being retrofitted with induction lamps which under UFC 3-530-01 are the only approved lamps for exterior lighting. Department of Energy (DOE) study indicates induction lamps have the possibility of 80-90 percent savings in maintenance costs over traditional high intensity discharge systems.
- LED technology will be incorporated in UFC 3-530-01 in the near future. LEDs are considered superior to induction lamps when applied in environment with low ambient

temperature. Refer to the newly published Interim Technical Guidance (ITG) 10-03: Application of Solid State Lighting (SSL)/Light Emitting Diodes (LED) for Exterior Lighting for more information.

- The use of the current solar powered light fixtures technologies is not recommended due to maintenance and reliability issues. However, they can be considered as an option if electrical service is not readily available in the area.

Re-lamping Strategy

- Scheduled or group re-lamping optimizes labor costs in comparison with on-demand re-lamping. Allowing lamps to burn out can also damage ballast. Savings in labor will outweigh the cost increase in lamp material. The optimum re-lamping period should be adjusted to actual operating conditions and occupant needs. This can be determined by the manufacturer's rated lamp life, or when an area starts burning out on a regular basis. This is commonly at 70 to 80 percent of rated lamp life.
- While re-lamping, remove dust/dirt to maintain design lumen output, which can reduce occupant complaints and help defer equipment replacement or upgrade costs. Clean fixtures run cooler, last longer and provide higher lighting levels.
- Lamp technology advances rapidly. When re-lamping, consider upgrading with newer and more efficient lower wattage lamps with same output.

De-lamping Strategy

- Eliminating lamps in areas with oversized lighting levels will save energy and maintenance cost.
- When de-lamping a lighting unit, make sure to remove ballast as well, as energy will be used even if the ballast runs without a lamp.
- When doing a lamp conversion, make sure lamp matches ballast. If ballast needs replacing, use lower wattage combination.
- Replace incandescent lamps with compact fluorescent lamp (CFL) which provide 60 percent or more in energy savings.

Spectrally Enhanced Lighting (SEL) is a lighting design technique that achieves a higher correlated color temperature (CCT) and color rendering index (CRI) resulting in a higher scotopic to photopic ratio. It provides better visual acuity thus allowing the lights to be dimmed and energy saved with no loss in visual performance. According to a DOE study in 2006, it can save 20 to 50 percent. As it gradually becomes more common practice, there will be more conclusive data and recommended parameters for SEL applications.

DAYLIGHTING is the preferred source for lighting as natural light offers better luminance than artificial lighting. Integrated with lighting control, it reduces the demand for electrical lighting, thus it reduces utility cost and prolongs lamp and ballast life, which in turn reduces the labor and equipment cost in maintenance and re-lamping.

Building Orientation, Windows, and Shading strategies are critical in setting up a facility for optimal daylighting. Control of passive heat gain from sunlight is critical in daylighting application. As it directly affects the temperature of the facility, integration with the HVAC and other building systems is required for accurate calculation of ROI.

The south side of a facility in the northern hemisphere will have direct sunlight, with a higher sun during the summer and lower sun during the winter.

- Using window film to control heat gain by blocking infrared and UV and allowing visible daylight transmittance should be considered.
- During summer, overhangs are used to block direct sunlight and heat gain from the high summer sun.
- In cooler northern climates, it is very advantageous to gain passive heat during the winter from a low south facing sun.
- Clerestories (high windows) with light shelves can be used to reflect sunlight or north facing clerestories without shades can be used to provide indirect light to the indoors. Due to their elevated height, for ease of opening and closing, clerestories and their blinds (if used)

should be controlled by a switch and automated control mechanisms.

- Vertical blinds should be used to shield direct sunlight, heat gain, and sky glare.

The north side of a facility in the northern hemisphere will not have direct sunlight

- Window film is not recommended.
- Vertical blinds can be used to shield sky glare.

The east side of a facility will have direct sunlight in the morning hours while the west side of a facility will have direct sunlight in the afternoon. Heat gain on the west side of the building will increase during the afternoon due to higher ambient exterior temperature.

- Overhangs can be used to block direct sunlight.
- Venetian blinds should be used to shield direct sunlight, heat gain, and sky glare.
- Window film should be considered to control heat gain.

Skylights when positioned and spaced properly with the proper lens systems, admit more light per unit area than windows, and distribute the light more evenly over the space. Skylights are mainly recommended in single floor high bay facilities such as warehouses, hangars, gymnasiums, and big box stores.

- The optimum material to use for skylights is either glass or acrylic. Double panes glazing along with a heat reflecting coating at the exterior pane will help reduce the heat gain transmitted through the skylight to the interior. White translucent interior lens diffuse and distribute light more evenly and create a soft even light within the space. Single pane skylights may weep and drip moisture when condensation builds up around the interior side of the skylight.
- The number of skylights varies based on climate, latitude and characteristics of the skylight. Four to eight percent of the floor area (evenly distributed) is a good rule of thumb to determine the optimum number of skylights for a space.



Double pane skylights with white translucent interior lens

- **Water Leakage:** The source of water leakage into a building is often hard to detect. If not installed or maintained properly skylights can be a source of roof leaks. Repair costs often extend beyond the repair of skylights, as water can cause damage to surrounding walls, fixtures, and electronic equipment. To minimize the possible leakage in skylights, NAVFAC Quality Assurance personnel must carefully inspect the curb height, flashings, and surrounding seals. Curb height is not to be less than eight inches above the roof and should be adjusted higher according to rainfall in the region. Refer to “The NRCA Roofing and Waterproofing Manual,” UFC 3-110-03, and building codes and ordinances for details on proper installation and height of curbs. Skylights should never be installed into a valley area of the roof where water can accumulate during rainfall. Skylights on sloped roofs should have crickets installed on the up slope side to divert water around the skylights.
- **Moveable Skylights:** Skylights with automatic reflectors for harvesting sunlight contain mechanical and electrical parts and may incur additional repair and maintenance costs.
- Protection screens or security grills can be installed if any of the following is a probable issue for the facility:
 - Roof susceptible to vandalism or break-ins.
 - Birds fouling skylights.

LIGHTING CONTROLS Capabilities are vast but their concept is simple: they provide the right amount of light only where and when it is needed. Integrated with daylighting, they can reduce the demand for electrical lighting. Unlike older systems, trained personnel are required to manage and maintain a sophisticated system.

Time Scheduling & Astronomical Time Clocks are used to switch lighting on and off for outdoor areas or where occupancy control is not appropriate.

Daylight Harvesting uses photosensors and dimmable lamp/ballast to reduce the requirement of electrical lighting in the presence of natural daylight. Controls must be integrated with the daylight design of the building. This technology carries a higher initial cost and a lower ROI than other controls technologies. Calibration is often very difficult. Completely turning banks of lights off rather than dimming can be considered in a high bay facility.

Task Tuning sets maximum or default light levels to suit the particular task to eliminate over lighting.

Occupancy Control turns lights on or off or dims based on occupancy. It should be used when occupancy is intermittent and unpredictable.

- PIR (Passive Infrared) sensors detect heat and are suitable when applied in small enclosed spaces.
- Ultrasonic sensors detect motion. They can be used in open spaces with obstacles as they are able to pick up motion behind objects such as desk and chairs. However, fabric panels or other natural moving objects can minimize their effectiveness and should not be used in such an environment.
- Periodically schedule to calibrate and maintain so that sensors operate correctly.
- Proper time delay in occupancy control switches can help mitigate the issue with having fluorescent lamps turn on/off too frequently, which shorten lamp and ballast life, and may increase cost of material and maintenance.

- Problems: When light turns on when not needed, check sensitivity (too high), sensor location, and surrounding motions that may trigger. When light turns off when occupant(s) are still in place, check sensitivity (too low), sensor location, and the time delay.

Personal Controls should be available to allow individual spaces to be controlled over on/off/dimming functions. Some individuals based on energy saving habits and/or preference will turn off or dim lights even during normal work hours. Currently, this is a cutting edge technology with a high cost therefore ROI is associated with high risk.

Variable Load Shedding is the automatic reduction of electrical demand in a building by shedding lighting loads, by switching off or dimming, to shave peak demand or reduce energy consumption. Load shedding should be done selectively by lowest operational priority areas first. This strategy carries a low ROI, especially if a facility already has a robust and efficient lighting system.

COMMISSIONING (CX) Commissioning of a lighting system is one of the most critical steps in sustainable lighting to get a high ROI. Daylighting, electrical lighting, and controls systems must be calibrated to work together for the system to meet its design intent. If not properly maintained and calibrated, the system will not function properly and can be “unplugged or abandoned,” resulting in zero ROI, reduced energy savings, and cost in accommodating changes. From the beginning of planning and design stage, the CX agent and the architect must communicate the design intent of the lighting and daylighting system. It is critical that complete sets of drawings, schedules, and specifications are provided to contractors, subcontractors, and suppliers alike.

After installation, the commissioning plan should include:

- If required by manufacturers, lamps should be “seasoned” before using the dimming function.
- All occupancy sensors are tuned to eliminate any false “triggers.”

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- Photosensors for daylighting control are to be calibrated, adjusted, and positioned properly to detect natural light.
 - Dimming controllers are set with the proper range to provide the correct light levels.

References:

Conley, Bill. Sustainability “How-To Guide” Series, Lighting Solutions. January 2010. IFMA Foundation. www.ifmafoundation.org

DOE. Lighting Business Case: A Reporting Analyzing Lighting Technology Opportunities with High Return on Investment Energy Savings for the Federal Sector. C. C. Jones, IALD, LC. E. Richman, LC. September 2005. Prepared by Pacific Northwest National Laboratory for the Department of Energy.

DOE. Maintaining Effective and Efficient Lighting Can Help Save Energy and Reduce Costs. August 2005. Prepared by Pacific Northwest National Laboratory for the FEMP.

DOE. Operations & Maintenance Best Practices A Guide to Achieving Operational Efficiency Release 3.0 August 2010. Prepared by Pacific Northwest National Laboratory for the Federal Energy Management Program. http://www1.eere.energy.gov/femp/operations_maintenance/om_bpguide.html

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